The Impact of Training in Integrated Pest Management among Nicaraguan Maize Farmers:

Increased Net Returns and Reduced Health Risk

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To assess the impact of training resource–poor maize farmers on the Pacific Plain of Nicaragua in the use of integrated pest management (IPM), 1,200 farmers received training during two years. CARE trained 13 extensionists and they provided intensive training to 60 promoter-farmers, who trained the 1,200 farmers. The farmers were trained in: the dangers of pesticides, recognition of the important organisms (pests and beneficials) in their fields, the biology and ecology of the organisms, how to determine pest population levels, how to choose the best method and product for control, and how to make decisions in the fields according to their new understanding and simple cost–benefit analysis. Three groups of farmers were monitored for two years: the intensively trained farmers (60 promoter–farmers), the trained farmers (1,200), and a group of "control" farmers who did not receive training during the first two years. After two years, the trained farmers used fewer pesticides, spent less money on pest control, made higher net returns, and suffered less exposure to cholinesterase-inhibiting pesticides than did farmers who did not receive IPM training. In addition, a comparison of cholinesterase levels of farmers who used personal protective equipment showed no reduction of exposure to organophosphate insecticides, compared with farmers who did not use the equipment. *Key words*: integrated pest management; pesticides; agriculture; training.

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Nicaragua imported an average of $24.38 million of pesticides (insecticides, herbicides, fungicides, and fumigants) per year during 1997–99. The average for the three-year period, including fertilizers, was $50.90 million. Importations (and use) of pesticides and fertilizers in Nicaragua rose rapidly during the 1980s, fell dramatically during the early 1990s, and have been relatively stable during the last three years (Figure 1). The dramatic rise of the 1980s was due to government incentives, including favorable exchange rates, subsidized credit, and government importation for use on state farms.[1] The dramatic drop in the early 1990s was caused by the removal of most of those policies and incentives, and the use of existing stocks. The current levels probably reflect real market demand.

Many farmers in Nicaragua are dependent on pesticides to manage their pest problems (insects, pathogens, weeds, nematodes, slugs, and rodents), while other farmers are increasingly seeking to reduce pesticide use, due to economic, regulatory, and market pressures. While the overall benefit of chemical pesticide use is often debated, the fact remains that most Nicaraguan farmers continue to use them.

The indirect costs of pesticide use have become increasingly documented in Nicaragua over the last 20 years. Pesticides are the most important occupational health hazard in Nicaragua. While the economic costs have not been calculated for Nicaragua, the impacts on human health, environmental contamination, and insecticide resistance have been demonstrated.

The human health costs have been amply documented. Pesticides cause direct, acute poisonings and deaths and chronic effects such as cancer, reproductive damage, immunotoxicity, and neurotoxicity.

In 2000, 545 people were poisoned by pesticides in work-related incidents in Nicaragua.[2] The crop with which most intoxications per area occurred was tobacco, followed by coffee. The pesticide most likely to cause poisoning was the organophosphate insecticide methamidophos, followed by the fumigant aluminum phosphide and the herbicide paraquat. Acute poisonings represent but a fraction of the total human health impact of pesticides.

Persistent central and peripheral neurologic impairment and psychological disturbances have been observed among workers previously exposed to organophosphate pesticides.[3,4] Miranda et al.[5] have demonstrated organophosphate-induced delayed polyneuropathy among Nicaraguan farmers.

The nematicide DBCP was used intensively in banana plantations in Costa Rica and Nicaragua during the 1960s through the 1970s. Thousands of workers who applied the pesticide have been shown to have azospermia and severely reduced sperm counts, and many were effectively sterilized.[6]

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Many cancers have increased occurrences among populations exposed to pesticides, including brain, stomach, lung, testicular, and prostrate cancers, and leukemia and Hodgkin's disease.[7] Pesticide exposures and the accompanying health effects not only occur at the level of the farm and rural community, but are carried to market and finally to consumers' plates, via the residues on crops, especially fresh produce. Salgado[8] found that of vegetables and fruits grown in the Sebaco Valley, Lake Managua shores, and in Jinotega, Nicaragua, 51% of the tomatoes, watermelons, cabbages, and potatoes were contaminated with pesticide residues above the permissible levels. One hundred percent of the lettuces, 70% of the cabbages, and 65% of the peppers had pesticide residues above the permissible levels.

Persistent pesticides, especially organochlorines, are found in almost all the water sources and soils of Nicaragua.[9] The use of organochlorines in agriculture has been banned, but there is recent evidence that they continue to be used clandestinely.[9]

Superficial fresh-water bodies, homes of fish and other fauna and a source of water for people, are highly contaminated with the pesticides used in conventional agriculture. Studies of pesticide contaminants in water and sediments from the Ochomogo River, the San Juan River and its tributaries, and the Great Cocibolca Lake showed contamination by organophosphates, organochlorines, and herbicides in the majority of the samples.[10,11] Pesticides in these three classes were related to a massive fish kill in the Los Guatuzos Wildlife Refuge near the San Juan River in June 1999.[12] The study sites were not even in the zones, such as the Sebaco Valley, where the heaviest use of pesticides occurs.

A direct and documented result of intensive use of pesticides in Nicaragua is the development of resistance to insecticides among certain species of pests. Intensive applications of pesticides create a selection pressure on populations for those few individuals in a population able to survive the application of the toxins. Over time the selected individuals become the dominant type in a population, leaving the once-effective pesticides ineffective. Along the road to resistance, farmers typically begin applying the pesticides in more concentrated doses and more often, in the vain attempt to kill the populations that at one time contained susceptible individuals. This escalation results in the "pesticide treadmill" and the accelerated selection for resistant populations. Hruska et al.[13] demonstrated that four important species of important insect pests in Nicaragua had resistance to the commonly used pesticides of up to 40,000 times that of susceptible populations.

The risks to farmers, farmworkers, consumers, and the environment posed by pesticides are widely accepted. All sectors of society, including the manufacturers of pesticides, recognize the risks posed by pesticides. But not all agree on the solutions.

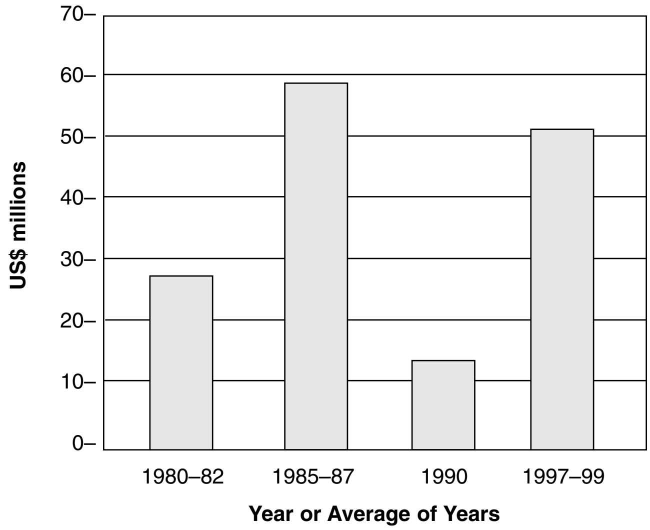

Figure 1. Trends in agrochemical importation into Nicaragua, 1980–99.

The pesticide industry identifies the problem as inappropriate handling and application of pesticides, with the remedy lying in the "safe and proper use" of chemical pesticides.[14] This logic contends that pesticides provide an overall benefit to society and that the negative health factors can be mitigated through protective equipment and farmer and farmworker training. Thus the solution lies in training the handlers, especially farmers, in the "safe use" of the pesticides.

An alternative view contends that there is no such thing as "safe use," especially in developing countries. In many areas combinations of cultural attitudes, poverty, unfeasibility of protective equipment for the climate, and poor enforcement of pesticide regulations create a context in which "safe use" of pesticides, at least for peasants in developing countries, is a myth.[15,16] An accompanying analysis points out that the goal of sustainable pest management should be to help farmers decrease their use of dangerous pesticides. Thus the goal becomes safer and more effective control of pests through better management and fewer pesticides, resulting in reduced health and environmental risks.

Better management of crop pests is the goal of integrated pest management (IPM). While the term has literally hundreds of definitions and is used by those who would severely reduce or eliminate the use of synthetic pesticides, as well as those who promote their sale, the general interpretation means that farmers should be better managers of their crops, to achieve both their goals and those of their families, as well as the goals of society. In order to do so, farmers must understand the biology and ecology of the agroecosystem, how to manipulate that system to minimize pest attacks and grow strong, healthy crops, and how to balance the costs and benefits of different options at hand, in case they need to take responsive action.

Some observers doubt that IPM is useful to resource-poor farmers in developing countries, because it either is too complicated, requires too much time or effort, is not economically rational for the farmer, or is an agenda pushed by researchers or others.[17] This opinion towards IPM use by resource-poor farmers in developing countries appears to be due to the observers' use of indicators of success that are useful for developed-world farmers, rather than developing-world farmers, their families, and their societies.

The Study Area and Background

The Pacific Plain of Nicaragua has some of the best agricultural lands in Central America. Deep, rich, young soils of volcanic origin, on flat and rolling terrain, with good rainfall, made the zone the breadbasket of Central America in the early twentieth century.

The zone has distinct wet and dry seasons with the rainy season lasting from May to November and December to April being dry (little or no rainfall). Within the rainy season, two cropping cycles are possible, with the first (*primera*) lasting from May to September and the second (*postrera*) from September through December. Resource-poor farmers traditionally plant maize in the *primera* and dry beans in the *postrera* in the zone. During the boom of cotton production, from 1950 through the early 1980s, cotton replaced much of the basic grain production in the zone.

Nicaragua in the early 1980s appeared to be the ideal environment for reducing pesticide hazards via regulations and enforcement. With a strong central government and an official rhetoric in favor of improved workers' conditions, it seemed quite possible to implement a U.S.-style system of tight laws and their vigorous enforcement. "Safe" pesticide use seemed quite feasible.

With this perspective, CARE Nicaragua in 1985 began a project with the Nicaraguan Ministries of Health and Labor, the Association of Small Agricultural Producers, and the Field Workers' Union. The focus of the project was to protect workers' health, through reducing pesticide exposures and training medical personnel to treat poisonings. Reduction of pesticide exposures was to be brought about through the introduction of appropriate technology, monitoring of pesticide exposures, training of field workers about the dangers of pesticides, and training of medical personnel in the treatment of pesticide poisonings. The technology that CARE chose to introduce and promote was closed loading systems for pesticide-fumigation planes, accompanied by the use of personal protective equipment, such as gloves, masks, and boots, for the workers on the fumigated strips and farmworkers.

CARE Nicaragua worked with the Ministry of Health to establish a pesticide-poisoning monitoring system, providing essential information about the numbers and patterns of pesticide poisonings. CARE also trained medical personnel in the correct diagnosis and treatment of poisonings. Additionally, CARE and the Ministry of Agriculture began cholinesterase monitoring, a simple blood test that detects exposure to organophosphate and carbamate pesticides. Farmworkers found to be at risk, as indicated by depressed cholinesterase levels, were removed temporarily from jobs that entailed continued exposures to pesticides.

CARE collaborated with the Ministry of Labor to enforce compliance of occupational hygiene laws of Nicaragua, via monitoring conditions on farms and notifying owners of unsafe conditions. CARE trained fieldworkers in safe pesticide use and the identification of pesticide hazards in their workplaces.

These efforts provided valuable experience, both within Nicaragua on how to reduce the dangers of pesticide use, and within CARE. For CARE the experience helped to develop the capacity to respond to the problems of pesticide use, as well as helped to question the prevailing institutional logic that the use of pesticides was an integral element in helping resource-poor farmers produce more food or profit.

By 1988 CARE Nicaragua had begun to review the pesticide project and to question both the success of its activities and the approach to solving problems created by pesticides. A review of the closed-circuit loading systems found that the technology could easily be misused, in fact increasing the health risk of pesticides. The systems were often used to load fumigation planes with water, while the concentrated pesticides were still hand-carried in splashing buckets. Masks were used well beyond the time that the filters became clogged with pesticides, increasing the inhalation of toxic materials. Leaking gloves provided a false sense of security, increasing exposures to pesticides. Ironically, the project demonstrated that the workers on landing strips that had received the closed-circuit systems and personal protective equipment had greater exposure to cholinesterase-inhibiting insecticides than did those on the strips that did not receive the equipment.[18]

Most of the protective equipment is not appropriate for the tropical climate of Nicaragua, where few farmers or workers will use masks, rubber gloves, rubber boots, and overalls at 40°C temperature. Even when appropriate protective equipment is available, resource-poor farmers for cultural reasons rarely use it.

This analysis led CARE to the conclusion that the project was not winning the battle of decreasing health risk, and that the project was missing a very important audience: farmers who made the decisions about what pesticides to use and how.

In the late 1980s the crops grown in Nicaragua changed dramatically. Due to a depressed world market price and the high costs of production, mostly caused by the 25–30 pesticide applications per season, the area devoted to growing cotton diminished rapidly, from 175,000 ha in 1986 to 1,750 ha in 1991.

Simultaneously, basic grain production was being encouraged on the Pacific Plain, as part of a nationwide food self-sufficiency program, a reaction to the civil war and embargo imposed by the U.S. government on Nicaragua. By 1988, basic grains, especially maize, accounted for the majority of the pesticide use on the Pacific Plain, and the majority of pesticide intoxications. Most of the farmers growing maize, and being poisoned with pesticides, were members of cooperatives that were formed under the agrarian reform of the 1980s. The majority of the newly titled farmers had previously been wage laborers on the cotton farms and had learned crop management that used 25–30 applications of pesticides per season. This tradition, stimulated by the government through its subsidy program for agricultural inputs, which formed part of the strategy of the self-sufficiency program, led to expected results: dramatic overuse of pesticides and very high poisoning rates.[1]

In July 1989, CARE Nicaragua redesigned the project to provide IPM training to 1,200 resource-poor basic grain farmers on 55 cooperatives, while maintaining the support for the pesticide-poisoning–monitoring system and the use of cholinesterase testing in the field. The project adopted a multisectorial approach, to solve the health risks caused by pesticides by providing farmers with better pest-management practices, and by measuring the impacts of the training on both crop production and health indicators. The project also explicitly sought to provide a bridge among the government Ministries responsible for responding to the situation, including Health, Agriculture, and Labor.

A group of agricultural extensionists, eight hired by CARE and five seconded to the program by the Ministry of Agriculture, was formed. A survey of 686 resource-poor farmers in the Departments of León and Chinandega on the Pacific Plain of Nicaragua was conducted. The survey provided baseline data against which the program has measured its success, as well as identifying the needs of the project farmers.

The results of the survey provided some startling results. Farmers were applying an average of seven pesticide applications per maize crop, at an average rate of 1.5 lt/ha per application. This rate is about 300% higher than recommended rates. Despite the heavy pesticide use, the maize yields were quite low (about 1,500 kg) and the farmers recognized two major biologic constraints to increasing production: the fall armyworm, *Spodoptera frugiperda*, and the cicadelid leafhopper, *Dalbulus maidis*. The former is an important defoliator, while the latter is the vector of three pathogens that cause stunting diseases.

Seven communities were chosen in the Departments of Chinandega (Aponsentillo, Tonalá, and Villa 15) and León (Las Marías, Malpaisillo, Posoltega, and Cristo Rey). These communities were chosen based on the following shared characteristics: a high concentration of basic grain production under cooperative administration, high levels of pesticide use, high levels of reported pesticide poisonings, and willingness to participate in the program. Fifty-five cooperatives were identified in the seven communities, with 1,200 members.

METHODS

Study Design

The project began in July 1989 with staff hiring and training, negotiations and contract signing with counterparts, the baseline survey, the development of the technical recommendations, selection of project sites, and the design of the monitoring system, including instruments for data collection. Data on crop yields, pesticide use, pesticide expenditures, and net returns to pesticide use were obtained during 1990 and 1991. Cholinesterase levels were measured in 1991. Data on pesticide use, yields, and in-the-field practices were collected via a field book to record all such activities. A sample of the farmers in each training group was provided with field books to record maize-production activities, costs, and results. The farmers were instructed in how to use the field books and supervised in their completion by the project extensionists. Records were corroborated with observations made by the extensionists.

The promoters were visited about weekly by the extensionists, who spent an average of four hours a week with the promoter. The promoters volunteered to carry out demonstration plots and exercises on their farms, and to train neighboring farmers, chiefly through group demonstrations and practices.

In addition to the trained farmers, a group of "control" farmers were monitored. They were matched based on geographic zones, area of crops planted, and types of crops grown with the trained farmers. "Control" farmers did not receive training during the first two years of the project, but were later offered training.

We compared pre–pesticide-exposure cholinesterase levels of 61 cooperative members with their levels during exposure. To obtain the preexposure values, we conducted tests during January through May before the agricultural cycle began and the farmers had manipulated pesticides. The majority had been free of exposure to pesticides for six to 12 months. We obtained preexposure values from nine promoters, 28 cooperative members, and 24 control cooperative members.

Eleven percent of the cholinesterase tests were done on promoters, 54% on program coop members, and 35% on control coop members. Of these, 94% were men, with an average age of 35 years (SD = 13.34), with a range of 15 to 79 years.

The effectiveness of the use of personal protective equipment in reducing pesticide exposure was also determined using cholinesterase tests.

Extension Methods

The IPM training component consisted of training farmers in simple techniques of reducing the use of pesticides on maize. Maize was chosen because it is the most widely planted crop, of major significance in the diet of the farmers, and the crop where the most pesticides were applied and with which most of the pesticide intoxications occurred. Integrated pest management tactics to reduce pesticide use were available through research that had been conducted both in Nicaragua and regionally.

The tactics chosen to promote IPM were: the use of an economic threshold, a decision criterion used by the farmer to economically optimize pesticide use, based on monitoring pest populations in the field, correct timing of pesticide applications, minimum dosage of pesticides, correct pesticide choice, and proper maize variety selection. These tactics were promoted and demonstrated through oral presentations, explanation of written materials, and demonstration plots, where the recommended techniques were compared with farmers' traditional practices.

The program chose as its extension method a system consisting of extensionists, "promoters," and "neighbor" farmers. The 13 extensionists worked closely with a group of 60 promoters, who in turn worked with 1,200 farmers. The promoters were farmers who were chosen by the communities in cooperation with the extensionists. The criteria used for their selection included leadership skills, respect in the community, interest in working as a promoter in the program, and being recognized by the community as being a good farmer. The promoters received no pay for their activities, but did receive intensive training; twice weekly visits from the extensionists, inputs for field trials (seeds and fertilizer), and educational materials.

The role of the promoter was to demonstrate to his neighbors that IPM was a good choice. This was done through field demonstration plots, field days to see the comparisons, distribution and discussion of educational materials; field visits to farmers in other parts of the country, and answering farmers' questions. The role of the extensionist was that of advisor to the promoter, trainer in training activities, and provider of technical information and help in identification of problems and possible solutions. The extensionist trained each promoter to be a good trainer, so that the extensionist could leave the training in the hands of the promoters.

The main focus of the training was how to be a better manager of pests and crops. The underlying message was that through careful observations and data taking, an understanding of the biology and ecology of the pests and crops, and an economic analysis of options, the farmers would make better decisions, based on their own perceived costs, risks, and benefits. This concept conflicted with that promoted by pesticide salesmen and traditional extensionists, who saw the role of the extensionist as that of an expert to provide specific recommendations of what pesticide to apply at the moment, without an explicit goal of leaving the farmer better able to make his own decisions in the future.

The techniques taught during the first year of training (1990) consisted principally in the management of two principal maize pests, the fall armyworm and the corn leafhopper. The first steps to managing pests are the correct identification of the pests, relating the pests to crop damage and yields, an understanding of insect ecology, including natural enemies, and entering fields to scout pest presence and estimate population levels.

Specific recommendations were suggested, but the emphasis was always placed on small-scale trials and self-learning, and not on teaching simple recipes as solutions. More about the extension method can be found elsewhere.[19]

Insecticide Use and Economic Returns

Data on pesticide use, including product used, date of application, dosage, and costs, and data on crop yields were collected via the field notebooks that farmers kept with the help of the extensionists. From these data the economic return of each group of farmers was calculated.

Cholinesterase Testing

Cholinesterase tests were conducted on 161 cooperative members of 30 cooperatives. Eleven percent of the examined workers were promoters (intensively trained), 54% were non-promoter project cooperative members (trained), and the remaining 35% were members of control cooperatives (did not receive training). Ninety-four percent were men. The tests were carried out between May and November 1991 by a team from the Ministry of Health, composed of a laboratory technician and an educator, and were supervised by the medical doctor of the program. The team traveled to the cooperatives and conducted testing in the field.

Only workers who had manipulated organophosphates in the preceding 30 days were included in the study. The previous manipulation of pesticides had occurred an average of nine days before the test. Fifty-six percent of the manipulations occurred within the preceding week, 80% within the previous 15 days, and 90% within the last 21 days.

The Cholinesterase Testmate Kit (EQM Research, Cincinnati, Ohio) was used to measure erythrocyte cholinesterase in blood samples. The skin of the left thumb of each worker was cleaned with an alcohol swab. A 10-mL sample of blood was extracted by punc-

TABLE 1. Effects of Training on Numbers of Insecticide Applications and Average Doses of Chlorpyrifos and Methamidophos

Training Group	Average No. of Insecticide Applications to Maize Crop	Average Dose of Chlorpyriphos (lt/ha)	Average Dose of Methamidophos (lt/ha)
Farmers with intensive training	0.95 (n = 57)	1.04 (n = 17)	0.49 (n = 6)
Farmers with training	1.45 (n = 70)	1.69 (n = 26)	1.16 (n = 13)
Farmers without training	2.32 (n = 19)	4.79 (n = 5)	1.14 (n = 5)
F-test	$p < 0.0001$	$p = 0.017$	$p < 0.001$

turing with a lancet and transferred to a solution of buffer, detergent, and quinidine. Oxyhemoglobin was measured with a colorimetric method. The reagent was dissolved in four drops of distilled water and transferred to the cuvette containing blood and buffer. Changes in absorbance reflecting cholinesterase activity were read. Results are automatically adjusted for temperature and presented as international units per gram of hemoglobin (IU/g Hb).

Each worker received his results from the test after participating in training on safe use of pesticides. If the value was lower than the recommended minimum, it was recommended that the worker be removed temporarily from further pesticide exposure and reexamined in 15 days.

RESULTS

Training had a highly significant effect on the number of insecticide applications made during the production of the maize crop. Farmers with intensive training applied 41% the number of applications of farmers without training, and farmers with normal training applied 64% the number applied by farmers without training (Table 1).

Training also had a significant impact on the dose of insecticide used in each spray. Farmers with intensive training applied 22% of the chlorpyrifos and 43% of the methamidophos doses of farmers without training. Farmers with normal training applied 35% of the chlorpyrifos and 102% of the methamidophos doses of farmers without training (Table 1).

Training (and the associated decrease in pesticide use) did not have a significant effect on maize yields (Table 2). However, the training did have a significant effect on crop-production expenditures (purchased inputs). Farmers with intensive training spent 70% of what farmers without training spent, while farmers with normal training spent 75% of what farmers without training spent on crop production.

The combination of the reduction of the expenditures on crop production and the similar yields resulted in training having a significant effect on net returns from maize production. Farmers without training lost an average of $24/ha, while farmers receiving normal training had a net positive return of $12/ha and farmers receiving intensive training had a net positive return of $43/ha (Table 2).

Pesticides Used

In the 30 days prior to cholinesterase testing, 76% of the farmers had used methamidophos, 47% chlorpyrifos, 30% parathion methyl, 12% deltamethrin, and 4% carbofuran. Other pesticides were reported by fewer farmers (Table 3).

Cholinesterase Levels

Forty-four percent of the farmers had been poisoned by pesticides previously at least once in their lives. The dates of the most recent pre-study poisonings ranged from 1966 to 1991. This does not reflect the annual incidence of poisonings, because some farmers had been poisoned several times. The average age was 35 years (SD = 13.3), with a range of 15 to 79 years. The mean cholinesterase level was 30.94 IU/g Hb (SD = 4.09) with a range of 19 to 40.3.

TABLE 2. Effects of Training on Maize Yields, Production Input Costs, and Net Returns

Training Group	Maize Yield (kg/ha)	Crop Production Input Expenditures (US$/ha)	Net Return (US$/ha)
Farmers with Intensive training (n = 31)	1,690	205.49	43.33
Farmers with training (n = 50)	1,560	221.80	11.86
Farmers without training (n = 11)	1,810	293.91	–24.04
F-test	n.s.	$p = 0.0011$	$p < 0.05$

TABLE 3. Percentages of Farmers in Training Groups Who Had Used the Indicated Pesticides within 30 Days Prior to Cholinesterase Testing

Pesticide	WHO Classification*	Farmers With Training (n = 105)	Farmers without Training (n = 56)
Methamidophos	Ib	69	91
Chlorpyrifos	II	47	48
Parathion-methyl	Ia	27	11
Deltamethrin	II	10	5
Carbofuran	Ib	6	2
Mephospholan	O	3	2
Acephate	III	0	2
Bifenthrin	II	0	2
Profenofos + cypermethrin	II, II	0	5
Monocrotophos	Ib	0	2
Fluazifop-p-butyl	III	1	0
Mancozeb	U	1	0
Paraquat	II	0	2
Atrazine	U	0	2

*Ia = extremely dangerous, Ib = highly dangerous, II = moderately dangerous, U = unlikely to present acute hazard in normal use, O = obsolete as pesticide, not classified (IPCS, 1998).

Comparison of Pre and Post-exposure Cholinesterase Values

The farmers who received the training showed no significant change in cholinesterase levels (+1.6%) while farmers without training showed a significant decrease (–17%), indicating exposure to cholinesterase-inhibiting pesticides (Table 4).

We analyzed the relative risk of having cholinesterase levels below the normal minimum value. To construct the normal range for our population we used values from 378 unexposed Nicaraguan agricultural workers during January through May 1991, obtaining a mean value of 33.19 iu/gr/hb (SD = 4.1, normal range 26.5–39.9). Twenty percent below the mean value is considered a depressed level, indicating significant exposure to cholinesterase-depressing pesticides. There was a significant effect of training on the proportion of farmers who had cholinesterase activity below the 20% below normal threshold (Table 5).

There was no significant relationship between previous poisoning and cholinesterase level. Fifty percent of the farmers who received the intensive training, 43% of the farmers with normal training, and 45% of the farmers without training had been poisoned at least once.

Use of Protective Equipment

Personal protective equipment is used in a very incomplete manner. Generally farmers use only one or two of the possible items of equipment (gloves, boots, masks, long-sleeved shirts, overalls). There was no significant difference in changes in cholinesterase levels between the farmers who used protective equipment, either individually or in combination, and the farmers who did not use the equipment (Table 6).

We also compared cholinesterase levels among farmers who used more than one type of protective equipment and farmers who did not use the equipment. The simultaneous use of the various items of protective equipment was very infrequent. The most frequent combination was boots and shirt, reaching 5%. The second most frequent combination was gloves and masks, with 3.1%.

DISCUSSION

The positive impacts of reducing dangerous pesticides use are many and have been amply demonstrated. In developed countries the focus on health impacts of pesticides has driven many of the most dangerous com-

TABLE 4. Changes of Cholinesterase Levels of Farmers with and without Training during the Pesticide Spray Season

Training Group	Mean Cholinesterase Activity (IU/ g Hb) Pre–Pesticide Exposure	Mean Cholinesterase Activity (IU/ g Hb) Post–Pesticide Exposure	Change* (%)
Farmers with training (intensive and normal)	31.47	31.51	+1.6
Farmers without training	35.67	30.88	–16.7

Paired *t*-test, p = 0.0009.

pounds off the market, and the use of potentially dangerous ones is severely restricted, with the restrictions usually enforced in the field and workplace.

The situation in most developing countries is quite different. Dangerous pesticides are often still legally sold, restricted use of dangerous compounds is often not developed, and whatever restrictions do exist are rarely enforced. The routine relative health risk to farmers and agricultural workers is much greater in developing countries than in developed countries. Any economic evaluation of pesticide use in developing countries must look very closely at the impact of current practices on health risk, and the potential for reducing that risk through innovative pest-management tactics.

This study clearly shows the benefits of providing training to resource-poor maize farmers in Nicaragua in a series of steps to reduce dangerous pesticide use. Training during a two-year period resulted in decreased pesticide use, lower costs, greater economic returns, and reduced health risk. There is no evidence from this study, however, that the use of protective equipment reduced health risk.

Similar results of other farmer IPM training programs on pesticide use, yield, and net returns have been found. The FAO-sponsored Indonesian National IPM Program found pesticide use was reduced by 40–50% and average expenditure on pest management decreased about 50%, while yields were not changed, as a result of training in farmers' field schools.[20]

TABLE 5. Low Cholinesterase Values of Farmers without Training and Farmers with Training (Intensive and Normal)

Training Group	Mean Cholinesterase Activity* (IU/ g Hb) < 26.5	≥ 26.5
Farmers with training (intensive and normal)	14	42
Farmers without training	10	137

*Fisher's exact test, $p = 0.011$.

Kishi et al.[21] examined signs and symptoms of pesticide toxicity of Indonesian farmers, comparing farmers during spraying and non-spraying seasons. They found significantly greater neurobehavioral, intestinal, respiratory, epithelial, and muscular signs and symptoms during the spraying season than during the non-spraying season.

This study is the first to have used cholinesterase levels to directly quantify the reduction in exposure to organophosphate pesticides as a result of training farmers to better manage their pests and crops. This method is very attractive, in that individuals can be followed from their individual basal (no organophosphate exposure) levels to their post-exposure levels. The direct connection between organophosphate poisoning, even a single incident, and persistent neurologic impairment has been demonstrated,[4] thus per-

TABLE 6. Impact of Use of Protective Equipment on Cholinesterase Levels

	Farmers Who Used the Equipment (n = 161) (%)	Mean Cholinesterase Activity (IU/ g Hb) Used Equipment	Did Not Use Any Equipment	p Value (t-test)
Gloves	5.6	30.66	30.96	0.82
Boots	15.0	31.25	30.89	0.70
Overalls	3.7	30.25	30.97	0.68
Long-sleeved shirt	11.8	30.34	31.03	0.50
Mask	14.3	30.25	31.06	0.79

Table 7. Impact of the Use of Protective Equipment on Cholinesterase Levels

Combination of Equipment	Farmers Who Used the Combination (n = 161) (%)	Mean Cholinesterase Activity (IU/ g Hb) Used	Not Used	t-test
Gloves + boots	2.5	28.57	30.84	n.s.
Gloves + boots + mask	1.9	27.30	30.89	n.s.
Gloves + boots + mask + shirt	1.9	27.30	30.80	n.s.
Boots + shirt	5.0	28.96	30.85	n.s.
Boots + shirt + mask	2.5	28.50	30.85	n.s.
Boots + shirt + mask + overall	1.9	27.70	30.86	n.s.
Gloves + mask	3.1	28.86	31.01	n.s.
Gloves + mask + overall	1.0	25.55	30.96	n.s.

mitting a direct linkage between depressed cholinesterase levels and health risk. This valuable procedure should be considered a key indicator in the evaluation of IPM programs, especially in developing countries, where organophosphate pesticide use is still quite important.

The assertion is made that resource-poor farmers do not use many pesticides and are not tightly linked to the markets, therefore do not have the incentives to implement IPM.[17] Goodell[22] viewed early efforts to help resource-poor farmers implement IPM and concluded that the IPM tactics promoted ran counter to the interests of the farm family, by increasing labor-intensive practices, or practices that promoted long-term, societal benefits, over the short-term goals of the farm family. Both of these assumptions clearly do not hold in this study or in the experiences from farmers' field schools in Asia: resource-poor farmers do use significant quantities of pesticides, but will reduce that use when they have greater knowledge and incentives to use more innovative pest management.

How much and what training is needed to achieve changes has been debated by practitioners. Although there is not a consensus on many points, there do seem to be emerging agreements about what elements of training do lead to changed behaviors and reduced health risks among resource-poor farmers: knowledge about the dangers of pesticides, especially specific compounds; the ability to identify the organisms in the field; an understanding of the basic biology and ecology of these organisms, especially those that are beneficial to the achieve the farmers' goals; growing a healthy crop to avoid pest problems; regular monitoring of field conditions to make decisions; and a pedagogic method that relies on self-discovery, rather than being taught concepts.

The continued use of IPM tactics, especially correct identification, observation of pest damage and numbers, and decision making based on the observations was documented in two ex-post evaluations of the project describe here. Hruska, et al.[23] and Pareja, et al.[24] found that 50–90% of program farmers continued to sample for insect pests three years after training ended, while only 17% on farmers who had not participated in the program monitored their fields to make pest-management decisions.

The "safe use" of pesticides paradigm promoted by industry does not seem to have a positive impact. Although the numbers are low, there was no significant reduction of risk as measured by cholinesterase levels as a result of the use of protective equipment. This apparently paradoxical result may have several explanations. One explanation is the true protection afforded by the equipment. Masks clogged with pesticides and gloves and boots with holes may indeed lead to greater exposure to pesticides than without the equipment. Garrod et al.[25] found that protective gloves almost always become contaminated inside; this would be especially the case when reusing gloves many times, as is the case with agricultural use. The false sense of protection may lead the farmer to engage in even more dangerous acts. McConnell et al.[18] found a similar result among fumigation-center workers with the introduction of supposed protective loading technology.

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